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The Role of Virtual Reality Simulation in Full Scale Joint Military Exercises

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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15. **Abstract:** What would the advantages be of being able to exercise our forces in a potential theater of operations, against known enemy capabilities prior to the start of a conflict? Having a good knowledge of the battlefield environment, the enemy and being able to test a plan in life like conditions would give an operational commander a distinct advantage. Through the use of advanced simulation techniques we are currently able to link together simulators and simulations from across the country or across the globe without having to put men and machines in the field. By employing this capability wisely an operational commander can select his forces, mobilize and execute his plan before any shots are ever fired. In this way he may be able to cut through the fog and friction of war.

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INTRODUCTION

In 1944, United States naval forces conducted live simulation exercises on the Hawaiian Islands in preparation for the Marianas campaign. What if Admiral Nimitz forces in the Pacific theatre in 1944 had been able to conduct their training on the Marianas before conducting the actual invasion? Suppose they had been able to view and operate in the battlespace before the actual battle began. This advantage might well have been translated in to a more efficient operation with fewer casualties and in general minimized the "fog and friction of war." Present day armed forces conduct a variety of live exercises in preparation for the next conflict. What if a Commander in Chief (CINC) of a Unified Command was able to assemble his forces, in theater, in response to a real world threat, and rehearse his plan before actually having to execute it? Would not the advantages of "having been there and done that" translate into a much more effective and efficient operation. If he had to execute it for real would not he, and the forces under his command, not do so with a greater degree of confidence? The ability to see the battlespace and operate within it prior to a conflict is a capability worth exploiting. Virtual reality (VR) simulation can provide the means with which to do it.

This paper will address the use of advanced simulation in military exercises and the implications for joint operational warfare. I will briefly describe the three types of simulation followed by a broad overview of the technology of virtual reality including some limitations. This is not intended to make the reader well versed in the technical details of virtual reality but to provide a basis for understanding its utility to the operational commander. The discussion of operational utility that follows will include a look at some past operations. The

specific cases mentioned are not for the purpose of providing lessons learned but to illustrate and clarify how any operation might benefit from advanced simulation. I chose the Marianas campaign because of the scale of the operation. Urgent Fury was selected because the after action analysis was the impetus for joint interoperability. I will conclude by making several recommendations.

TYPES OF SIMULATION

There are three different types or levels of simulation. Live simulation is the most commonly used and consists of putting men and machines in the field, at sea and in the air either at a test range, a bombing range or air to air combat range. Operations are simulated using a combination of role playing, tactical maneuver and live fire exercises. Live simulation evaluates the warfighting skills of individuals or entire units within the constraints that the test range and personnel safety impose.

The second type or level of simulation is constructive simulation. An example of this type of simulation is wargaming and it is used primarily as a means of training commanders and their staffs. A constructive simulation is driven by a computer program. It encompasses the range of scenarios from land, naval or air engagements to a combination of any of the three. Size and makeup of friendly forces, theater of operations, composition of opposing forces and the related scenario are all fed into a computer. Sophisticated graphics and three dimensional mapping allow the engagement to take place anywhere in the world. The lowest level elements in the simulation may be an entire unit rather than individual tanks, aircraft, ships or infantrymen. There are no forces in the field and no actual interaction between combatants. The computer runs the simulation and determines the outcome. The data is

entered and the computer does the rest. As the game progresses, command decisions are input into the simulation. In this way command, control and communication skills are tested.

The third level of simulation is virtual reality. In virtual reality simulation the user in effect, steps through the screen and is immersed in the simulation, interacting with the computer generated environment. The distinction between the computer system and the users environment is removed, they are one and the same. The user can enter the simulated environment or battlefield and explore it by sight, sound and touch. The battlefield used can be any real world location - like a potential threat area. Present technology can incorporate enemy forces (i.e. ships, subs, aircraft, weapons etc.) and non-combatants (i.e. merchant vessels, commercial aircraft etc.) into the simulation. This allows for a scenario to be run based on projected enemy capabilities and a more realistic evaluation of a particular plans' viability. Virtual reality combines the man - in - the - loop aspect of live simulation, with the actual operational battlespace of constructive simulation, to provide the most realistic possible training environment. In the first historically accurate simulation of an actual battle (the "Battle of '73 Easting during Desert Storm), soldiers in tank simulators actually experience all of the physiological reactions they would in actual combat. The utility of VR simulation to an operational commander lies in this physiological reaction of an actual soldier to a synthetic battlefield.[1]

[1] James Kitfield, "Trading Bullets for Bytes", Government Executive, June 1994, 19

TECHNOLOGICAL ASPECTS

Various technologies are employed in order to immerse the user in the virtual environment. (Immersion as used here includes the ability to view the virtual environment in 3-D for 360 degrees, move about freely and grasp and manipulate objects in that environment.) True to life graphical representations in three dimensions are key to a virtual reality system. This is normally accomplished with a head mounted display (HMD) which isolates the visual sense from the real world. As the user adjusts his/her head position the scene in the HMD changes. Another method is projection screens like the ones used in an aircraft simulator. The visual display consists of either a 3-D projection seen through the windscreen or onto the walls of the room in which the device is located.

A nylon bodysuit containing optical fibers tracks user position and orientation. Computer generated audio duplicates what is heard in the real world providing direction and distance cues. Data gloves are worn to provide a sense of touch and treadmill equipment allows an individual to 'walk through' the synthetic environment.[2] In a vehicle simulator (i.e. aircraft, ship or tank) movement is created by changing the orientation of the device(vehicle) to control inputs or terrain changes as the scene scrolls by on the visual display.

In order to execute an operation on the virtual battlefield a CINC must assemble his forces in theatre. Obviously the need for more than one simulation device exists to accomodate all the players in a particular exercise and they must all be connected in some way. Through the use of an electronic co-location technology called Distributed Interactive Simulation (DIS)

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[2] Roger D. Smith, "Virtual Reality Merges With Battle Simulation", Signal, July 1993, 52

multiple dissimilar simulators (tanks, ships, aircraft) can be networked to operate in a real-time simulated environment. DIS allows simulations to take place simultaneously from different geographic locales but in a common synthetic battle space where each participant is autonomous.[3] Tank units in Germany can conduct maneuvers with tank units in Kentucky or helicopter squadrons in Alabama. The mediums used to accomplish this include telephone lines, fiber optic cables, and satellite transmissions.[4] DIS allows events in the simulation to occur in what is known as a seamless manner. Despite the time lag associated with the information transfer that allows simulators to interact, events appear to the participants as happening in real time with no perceived delay in the action.[5]

Augmented Reality, also referred to as embedded technology, allows various weapons platforms to participate in simulations via a computer program run through the on board command and control system. The platform can be operating or stationary (i.e. underway or pierside, airborne or on deck). For example, the Navy's Battle Force In-Port Training Program allows a ship at pierside in Norfolk, Virginia to be electronically relocated to any position in the world and simulate a cruise missile strike on a land based target or engage an enemy ship or sub in combat. The vessels' instrumentation displays all the indications it would in the actual environment including position, heading, speed, etc.. Location of enemy aircraft, ships and incoming as well as outbound missiles show up on radar as they would in a real combat situation. DIS makes it possible for several platforms to participate in the same simulation using this embedded technology. For example, a submarine in New London,

[3] Kevin Correll et. al., "Undersea Warfare Networked Modeling and Simulation", Unpublished Research Paper, Naval Undersea Warfare Center, 1997

[4] Ronald W. Tarr & John W. Jacobs, Ph.D., "Distributed Interactive Simulation (DIS): What Is It And Where Is It Going?", Proceedings of the SCSC '95, July 1995, 1019

[5] Ibid., 1011

Connecticut and a surface combatant in Norfolk could combine in a cruise missile strike on a land based target followed by a carrier air strike directed from a carrier in San Diego, California with the strike being conducted by pilots in simulators at Lemoore, California. Interoperability is facilitated because elements from all of the services can participate in the same simulated exercise. DIS also provides for the ability to quickly convert simulators that simulate a variety of equipment - one type of aircraft, tank or ship to another. Reconfigurable simulators may make it easier to represent a certain mix of forces. It is important to note that DIS is not a static but a dynamic capability. It can expand and incorporate new technologies or technological advances as they emerge.[6]

An advanced simulation capability like virtual reality holds considerable practical advantages. It allows an exercise to be conducted without putting men and machines in the field. Electronic co-location could place the forces apportioned to a CINC, as well as units from a supporting CINC, at his disposal without having to move them from their home base or home port. Of course this would require a level of jointnes and mutual cooperation as yet unseen within our military. Those issues would have to be worked out at the Joint Chiefs of Staff and CINC level and at any rate are peripheral to this discussion.

Simulation would allow us to do things safely we would not otherwise be able to do, unconstrained by weather or time of day. It would also alleviate the expense of live simulation. The costs of operating ships, aircraft and tanks runs into the millions of dollars. The high cost of modern day weapons systems can make live-fire training exercises prohibitively expensive. A single live missile can cost tens of thousands of dollars and

[6] Ibid., 1010, 1015

certain types of ammunition can be as much as one dollar per round making infantry combat maneuvers an expensive proposition.[7] Virtual Reality eliminates all of these concerns while enabling ship, aircraft, tank drivers and dismounted infantry men to operate their weapons systems just as they would in the field. Using the Conduct of Fire simulator, U.S. Army tank crews have improved their tank gunnery skills while having to cut back on live fire field training exercises.[8]

Available training space is also at issue. Since the WWII era the amount of space required for a fighter aircraft to conduct standard maneuvers has grown from five to 40 miles, an Army mechanized battalion from 4,000 to 80,000 acres. Training ranges are not growing to accommodate these requirements, rather they are shrinking or disappearing altogether through a combination of various factors including environmental, political and budgetary.[9] Present technological capability is able to address much of the training space concern while future advances will eliminate it altogether.

CURRENT LIMITATIONS

For all of its current capability and the future promise it holds the technology of virtual reality is not without its limitations. There are several factors affecting simulation fidelity. Fidelity in this case refers to how clearly the simulation matches real world characteristics and its ability to produce life like responses to events happening in it.[10] Fidelity is therefore crucial to the 'reality' of virtual reality. The calculations required for high fidelity three dimensional graphics places a premium on computing time. Computing power at present

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[7] David Alexander, "Military Applications for Virtual Reality Technologies", Military Technology, May 1993, 54

[8] Kitfield, 22

[9] Ibid.

[10] Tarr & Jacobs, 1013

forces a choice between a fuzzy image that the user sees in real time or a detailed image that appears to lag behind what is expected. In either case the effect is less than desired. The goal is for a highly detailed image of video quality. This will have to wait for faster, more powerful computers.

Head mounted displays, body suits and data gloves also present problems in terms of systems lag, freedom of movement, and comfort level for the user. What is required are light weight, self contained devices, unconstrained by electrical tethers, that provide real time position and tracking and are sensitive enough to respond to the slightest movement.[11]

Issues affecting DIS include the lack of common terrain and oceanographic data bases and differing levels of sophistication between simulators. There are also difficulties associated with the capacity of a network to transmit the high volume of information required to maintain seamlessness - particularly during the large scale exercises envisioned here.[12]

The problems cited above are all being addressed in one forum or another. The military is by no means exclusive in the use of this technology. Applications for VR exist in industry, education, entertainment and the medical profession. All of these customers diverse needs are driving the advances in VR. In the past ten years the processing power of a microchip has increased by a factor of 10. As a result, image generation has improved dramatically. My research indicates that most, if not all, of these problems will be solved in five to ten years.

[11] Maj. James E. Haywood, USAF, Improving the Management of an Air Campaign with Virtual Reality (Maxwell Air Force Base, Alabama: Air University Press 1996), 12
[12] Tarr & Jacobs, 1018

APPLICATION

"Advanced simulations lend themselves to solutions to a lot of post-cold war circumstances, especially when you consider that the potential fog of war is thicker now for the lack of a clearly defined enemy."

Jan Anton, Program Manager for the Army's Battlefield Distributed Simulation program[13]

The military applications for VR are currently at the tactical level. The Army's SIMNET and Combined Arms Tactical Trainer, and the Navy's Battle Force In Port Training Program discussed previously are examples. The Marines and Air Force as well are exploring the use of VR for tactical training. All of these applications are of great value in improving the readiness and proficiency of our forces and their use should continue. The focus of this paper, and where I believe we stand to benefit the most from advanced simulation is from an operational standpoint. What I propose is employing this technology at a joint operational level. This would be accomplished by combining elements of all four services and, political and security considerations permitting, allied or coalition partners forces in a virtual battlespace that is a replica of some real world location. The scenario should be taken from a plan devised by a CINC staff in response to a potential or actual real world contingency. This would provide for more realistic appraisal of force capabilities as well as a particular plans' chances of success or failure. A good plan could be made still better by fine tuning in response to concerns generated in the simulation. VR would allow the simulation of any threat, from operations other than war, to full scale combat on the order of Desert Storm, anywhere in the CINC's AOR, day or night, in any kind of weather.

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[13] Kitfield, 20

"Decisive warfare in the theater can be achieved by application of sound operational concepts. Operational art also allows a highly capable, well trained, and skillfully led force, guided by a sound strategy, to defeat even a much stronger opponent."

Professor Milan Vego[14]

Within the operational sphere are several key areas that a virtual reality simulation capability could address. The first of these is deterrence. One of the purposes of having a military is to deter an attack by a potential enemy. A true to life training capability, well advertised to that enemy, could act as a very potent deterrent.[15] According to Dr. Anita Jones, director of research and engineering at the Defense Department, advanced simulations strengthen the basic human intellectual processes.[16] Put another way:

"Just as people remember events from a movie more clearly than those from a book, virtual reality can be used to embed lessons in the human brain more deeply."

Roger Smith, senior simulation engineer, Mystech Associates[17]

Being able to fight the battle in the simulated environment before the start of actual hostilities gives our forces an unprecedented advantage and is something a potential enemy would have to take into account during his assessment of our capabilities. Reactions to changing situations would be quicker and decisions made faster, as a result of having rehearsed the plan. Viewed in this way, advanced simulation becomes a force multiplier.

Virtual reality would reinforce the planning process. In an advanced simulation all of the factors that a CINC must consider including force structure, logistics, C4I, operational deception, sequencing and synchronization can all be played out much as they would in

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[14] Milan Vego, "Operational Art", Unpublished Research Paper, U.S. Naval College, Newport, R.I. 1996, 1
[15] Ian Strachan, "Salvation Through Simulation", Janes Defense Weekly, November 1994, 26
[16] Kitfield, 19
[17] Smith, 54

reality.[18] For example if the determination is made that overwhelming force is not needed how then are the forces tailored to meet the contingency. What is the appropriate force level and structure. How much is enough? Various sequencing and synchronization schemes could be tested to determine the optimum mix of combat elements, type and rate of firepower and target selection that will gain the objective in the least time with the fewest casualties. While the staff may have wargamed all of this before putting the plan on the shelf, seeing it in actual practice on the battlefield would go a long way toward bringing the unforeseen into clearer focus, allow for more detailed planning and result in a more sophisticated operational design. Even more importantly, VR would involve the human element that wargaming doesn't.

Both deliberate and crisis action plans could be rehearsed. Networked simulations would allow for a shorter time between rehearsal and real world deployment. The CINC or whoever he designates to run the simulation could focus on any part of the plan or run it in its entirety. The computer would provide the ability to stop the simulation at any point or run the same evolution over and over until the coordination between all combat elements and between combat and supporting elements was closely orchestrated. The use of advanced simulation would thereby mitigate much of the fog and friction of war.

The greatest benefit may be in the protection of our own center of gravity. I refer here to national will and what has become a historically low tolerance on the part of the American public for protracted conflicts and battlefield casualties - the enemy's and our own. Even in the most successful military operation in recent history, Desert Storm, this factored in to the

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[18] Lt.Col. David A. Bartlett & Maj. Robert F. Curtis, USMC(RET), "Why Not A Commandant's Wargame and Simulation List?", Marine Corps Gazette, July 1994, 30

decision making process. A highly trained force, that has been tested against enemy capabilities, executing a sophisticated plan it has already practiced, in a battle space it is familiar with, would make for a very formidable foe. Such a force would no doubt operate with a high degree of efficiency. All of these factors together would bring the enemy to a more rapid culminating point and translate into fewer casualties.

One way to illustrate the impact VR could have is to examine the possible effect on past operations. The 1944 invasion of Saipan was beset by several problems. The Navy guide boat led the leading waves of the amphibious landing off course. Amphibious vehicles had trouble locating the few points of ingress onto the beach. Unit integrity broke down with some becoming scattered while others became entangled with one another, creating confusion and complicating command and control. The amphibious tanks that were used did not have the armor or armament of land tanks and were vulnerable to Japanese fire. In addition, they were stopped by minor obstacles. Amphibious tractors were slow and lightly armored, making them, and the troops they carried easy targets. As a result, none of these vehicles reached their initial objectives which were as much as a mile inland. Troops were left to fight on foot for every inch of territory.[19] All of these things added to the level of confusion and the number of casualties. Advanced simulation would have exposed all of these problems before U.S. forces ever faced enemy fire. The crew of the Navy guide boat would have known what objective to steer for because they would have already seen it and made the approach to the beach several times. For the same reason the amphibious vehicles would have known where the points of ingress were. Advanced knowledge of the

[19] Philip A. Crowl, The War in the Pacific , Campaign in the Marianas, United States Army In World War II (Washington, D.C., :Office of the Chief of Military History, Department of the Army, 1960), 83-86

vulnerability of amphibious tanks and tractors quite possibly could have led to a decison to employ land tanks, or to major changes in the plan such as a change in the site for the landing, a more intensive bombardment, or a combination of the two. What should be clear in any event is that a more precisely executed operation, with minimal confusion and fewer casualties would have resulted.

Operation Urgent Fury in 1983 was the catalyst for the emphasis on joint interoperability that exists today. The essence of the problems that beset that operation can be distilled into the widely reported experience of an infantryman having to call in fire support by making a long distance call back to CONUS using his calling card. How much more efficient and well coordinated the sequence of events would have been with the benefit of a virtual reality simulation conducted beforehand. The C4I capabilities of the task force, and more importantly its shortcomings, would have been exposed. Equipment incompatibility, differences in terminology, flow of information are all issues that an advanced simulation would have highlighted. The sequencing and targeting of fire support would no doubt have been rehearsed quite possibly eliminating the need for the phone call referred to above.

CONCLUSION

During the course of my research I interviewed two gentlemen who are currently working in this field and have personal experience with many of the concepts and capabilities discussed in this paper. I asked them the following question: If full cave virtual reality is the ultimate in virtual reality technology, how far away are we from having that? By full cave, I mean a simulator that can reproduce, in a room, any environment we choose, in three dimensions, with a continuously scrolling scene capability, that allows the user to experience

sight, sound, scent and touch the way one does in reality and in which the user can discern no difference between the simulated environment and the actual place being simulated. (Fans of popular science fiction may recognize what I am describing here as a holodeck.) The answer I received from both of them in independent interviews was ten years.[20]

While full cave virtual reality may be ten years off there are things we can do now to exploit advanced simulation. First, network live infantry simulations on instrumented ranges with augmented and existing virtual reality simulations and expand on the deployable capabilities that already exist. Second, we should continue to advance, promote and encourage joint networked simulations with a view to increasing the number of participants in each exercise as well as the number of exercises. Multi service participation is extremely important to exploiting the full potential of this technology. Third, put research and development dollars behind the technology to the maximum extent possible and use off the shelf capabilities from the private sector as they become available. Regardless of how much money we are able to devote to it, we should continue to expand our use of existing advanced simulation capability even as the technology continues to mature. It is this writers opinion that simulation has historically been an underutilized asset. In my own personal experience in the aviation community I observed a great reluctance for and resistance to using the simulator. It seemed to be an institutionalized bias. This is probably more attributable to a lack of sophistication of the device more than anything else. Pilots felt that the simulator just did not match what one saw and felt in the aircraft closely and in some

[20] Interviews with Mr. Carl Salvo, senior systems analyst, Systems Engineering Associates Corporation, Newport, R.I.: 22 January 1997 and Mr. Alan Tsakaeras, computer engineer, Naval Undersea Warfare Center, Newport, R.I.: 24 January 1997

instances that could lead to discomfort or getting sick. The present level of sophistication has obviated that argument and as the technology advances the quality of simulation will only get better. I predict that within ten years simulators and simulation will become so life like that the user will not be able to discern any difference between the simulation and the real thing. The military should be poised to take full advantage of that capability.

There is a debate being conducted today inside and outside the military that centers on whether or not we are undergoing a Revolution in Military Affairs (RMA). Virtual reality may not in and of itself constitute an RMA, but it is a revolutionary tool that an operational commander can use to good effect. The revolution may lie in how we put this technology to use. It needs to encompass the joint operational, as well as the tactical level. The technology may not be fully developed but there is enough existing capability to make it well worth our while. It is an investment that will return savings in machines, money and lives.

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